NASA Contractor Report 195389

Final Report on Procedure for Installation of PdCr Gages by Flame Spraying

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FINAL REPORT

ON

PROCEDURE FOR INSTALLATION OF PdCr GAGES BY FLAME SPRAYING

TO

NASA LEWIS RESEARCH CENTER
CLEVELAND, OHIO

UNDER NASA CONTRACT NO NAS3-27038

By: S.P. Wnuk, Jr.
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Ayer, MA 01432

Introduction

This document contains the installation procedure employed under NASA contract NAS3-27038. They represent the state of the art at the time of this project.

References

1. Lei, Jih-Fen, "Development and Characterization of PdCr Temperature Compensated Wire Resistance Strain Gage," *Fourth International Conference of Machine Perception Technology*, Cleveland, OH, September 1989

2. Strain Gage Development Lab, Hitec Products, Inc., "Flame Spray Attachment Procedures"

3. Strain Gage Development Lab, Hitec Products, Inc. "Strain Gage Installation Accessories Catalog"

4. K. Krake, "Proposed GWP-29 Thermocouple Installation," NASA Dryden, 6/15/93

Facilites:

The facility requirements are covered in Reference 2 "Flame spray Attachment Proceedure" and should be adhered to. The facility should contain the following equipment as described in Reference 2:

1. Flame spray booth
2. Gasses
3. Air compressor
4. Air conditioner/ dehumidifier
5. Bench with microscope
6. Grit blast equipment

Flame Spray Equipment:

The following items of equipment are specified for the installation of PdCr gages. See Reference 3 for description of part numbers (P/N),

1. Hitec Products CM-1000 Powder Flame Spray System, P/N #200120 (for spraying Nickel Chromium Aluminum pre-coats).

2. Norton Co. Rokide Flame Spray System, P/N #200201

3. Vortex Air Cooler, P/N #200140

4. Air filter, desiccant type, 20CFM minimum capacity

Materials:

1. Rod, Rokide, Hitec HTZ, 1/4" x 18"

2. Powder, Nickel Aluminide, P/N #200149

3. Tape, Flame spray mask, Telfon Fiberglass, P/N #200154

4. Tape, FLame spray mask, Aluminum, P/N #200154A

5. Methyl Ethyl Ketone (M.E.K.) solvent

Tools:

1. Machinists square, Starrett EDP 50118 14D

2. Scribe

3. Carbide tip scribe in aluminum holder

4. Tweezers, Dumont 3 C(2)
5. Industrial razors, package, single edge
6. Dresser stick, aluminum oxide, white, 1/4 x 1/4 x 4", 60 grit
7. Pencil, red
8. Pencil, silver
9. Scale, machinist's, 6" with decimal graduations
10. Microscope light
11. Eye protection, clear with side shields
12. Eye protection, #5 shade with side shields
13. Ear protection
14. Igniter
15. Rubber mallet
16. Welder's gloves, leather
17. Shop coat - cotton
18. Glass plate, 2" x 6" double thickness pane (4)
19. Resistance meter, Beckman 850 or equivalent
20. Artist's brush

Procedure

The steps described in the text below are augmented with photos and sketches at the end of the text.

1. Solvent clean gage bonding area using appropriate procedures for the material being used. This presupposes that the parts are free from contaminants. If the parts are oxidized due to exposure to elevated temperature, the oxides must be removed by abrasion with 600 to 1800 grit silicon carbide paper, or by light grit blasting with an S.S. White airbrasive unit (or equivalent).

2. **Layout gage and thermocouple locations.**

   Using machinist layout tools accurately lay out gage and thermocouple center lines and outline the gage and thermocouple bond surface. For a 120 ohm gage made with 10 mil diameter pins, the gage area required is 0.4" long x 0.280" wide. The thermocouple bond area is .075" wide x 0.100" long. If desired, the Rokide pre-coat may be extended to insulate under lead joints. An additional 0.1" of pre-coat extending beyond the end of the gage is sufficient to protect cable-gage lead splices. This extended pre-coat makes the gage layout dimensions 0.500" long x 0.280" wide.

   A ball point pin with a carbide ball may be used for layout. The carbide ball will roll over surface imperfections and, after the ink is removed with solvent, the light line made by the ball is visible. This line introduces a small compressive residual stress and is usually not objectionable. Do not use ballpoint pins with stainless steel or plastic balls, because these will wear out almost instantly. A machinist's scribe may be used if not objected to by the project management. Also, red colored pencil's have been used for layout. Colored pencil layouts are not as accurate as a scribe but not as objectionable. Do not use ordinary lead pencils because these contain carbon which should not come in contact with many high temperature alloys.

3. **Mask thermocouple locations for grit blasting.**

   Using 1" wide silicone tape (P/N 200154 SA) mask the part for grit blasting. Place the tape 0.010" to 0.015" outside of the scribe line around the thermocouple area to be grit blasted. The grit blast intensity diminishes to zero at the tape edge and therefore the additional 10-15 mil perimeter is required to fully expose the bond area to the grit blast. Grit blast the exposed area using a grit and blast pressure as recommended for the test material. A #30 to #46 Aluminum Oxide grit using 60 to 120 PSI air pressure is usually required for good Rokide adhesion. Examine the surface under the microscope to insure adequate roughness before removing masking tape. Clean gage and thermocouple area with MEK after tape removal.

4. **Nickel Aluminide Pre-coat**

Mask the gage bond area perimeter using Teflon Fiberglass flame spray masking tape (P/N 200154). This tape is applied exactly on the scribe line perimeter. Do not touch the gage bond area with the tape adhesive because silicon contamination from the tape may cause poor bonding of coating. Press tape firmly in contact with the surface, especially where tape layers over lap. Tape must be well bonded to the surface to prevent lifting of tape caused by heat from the flame spraying process.

Using the Hitec Products Mini-Gun for metal powder (P/N 200101) apply nickel aluminide metal pre-coat (P/N 200149) using standard operating procedures described in the operation manual. Apply 2-3 mil thick coating and examine for completeness of coverage using microscope. Coverage should be 95-99% complete. Move a light source at varying angles while examining the coating. A slight reflection from the original surface should be observable. Excessive coating thickness can cause warpage of the part on thin specimens. An ideal coating is one layer thick. Once the flame spray particles begin bonding to each other, they will cause distortion because of a differential in thermal expansion coefficients between the structure and the coating. A properly applied coating provides a surface texture equivalent to a coarse grit blast. This coating eliminates the need for grit blasting as a surface preparation method. The flame sprayed metal coating is easier to apply, and prevents part distortion commonly encountered with grit blasting. Also, nickel aluminide can be applied to materials that are too hard to grit blast.

On thin parts, less than 1/8" thick, application of Vortex cooling air speeds up the coating process. The parts should not become too hot to touch during any time of the coating process. Good application technique will always keep the part cool. Application of the coating to hot parts will cause some undesirable distortion. The cooling air must be desiccant filtered to remove all oil or an oil-less air compressor should be used.

Remove masking tape and gently run an industrial razor over the coating to remove any loose particles and blend the edges. An excessive buildup always occurs at the tape edge and must be removed. A clean wire brush (with very small bristles) may also be used to gently remove any loose particles. Be sure the wire brush is never used for other applications where it may be tainted with oil or other contaminants.

5. **Apply Ceramic Pre-coat**

Remask using Teflon fiberglass tape. Place the tape exactly at the edge of the nickel aluminide pre-coat. Place the part in the flame spray booth in a suitable vise, and apply 30psi of vortex cooling air. Using Hitec HTZ rod, apply a 2-3 mil pre-coat over the nickel aluminide. The pre-coat will appear grey. If the coating appears white, it is too thick. Examine the grey coating under the microscope to be sure it is continuous.

6. **Apply Gage**

Remove gage slide from package and examine gage under microscope. Remove tape dot from the gage leads. Place slide on clean surface with leads pointing to right and cut near side tape carrier tab at the junction with cutouts. This is accomplished using a single edge industrial razor placed at the tab - cutout junction and press down, cutting through the tape carrier. With the razor still in position, grasp the solid tape tab with tweezer and remove. Using the tweezer, grasp the uncut tape carrier tab and carefully lift upward, removing the gage from the slide.

While viewing the gage location under the microscope set at 7x, hold the gage in position just above surface with the tweezer. When satisfied with gage position press down on the gage lightly using finger of free hand. Do not remove and reposition as this destroys the tape adhesive. It is most important to have good tape adhesion. The gage should be located so there is an equal margin on the three free sides of the gage. Using a blunt tweezer, press on tape bars near leads to be sure all tape adhesive is in intimate contact with pre-coat. Do not press hard on tape above wire strand. i.e. Do not conform wire strands to the contour of the Rokide surface. Heat treated PdCr wire is somewhat brittle and can be broken with excessive pressure from tweezers. Examine grid wires adjacent to leads to be sure these wires are not above the surface.

Cut a 1/2" long x .030" wide tape bar of aluminum flame spray masking tape (P/N #200154A) and place over leads as shown. Be sure tape does not go over or touch the one mil PdCr wire. Press the tape bar in place over leads using tweezers to bend aluminum to comply with shape of gage leads. This tape, once bent, will not spring back, as does the fiberglass tape, and has much more holding power than the fiberglass tape adhesive. Place a piece of 0.040" wide double thickness fiberglass shading tape over the 0.030" aluminum tape bar with equal overhang on each side. Place appropriately sized shading tape over each gage tape bar. Cut two 1/8" lengths of 0.030" wide double thickness fiberglass tape and place these over the platinum crossover wire at top of gage, as shown in Figure 9. These tape bars hold the platinum wire in place during flame spraying. Measure gage resistance at ends of leads and record. Measure to nearest 0.1Ω.

Next, the gage is boxed in by placing a single layer of fiberglass tape on all four sides and located about 1/64 to 1/32" away from the grid. The first tape layer should go over leads with tape starting half way across the lead tape bar. The second tape layer goes over top end of gage. The next two tape pieces are placed along the sides of the gage. Press all tape firmly in place using tweezers or fingers. Check to be sure grid is bonded by pressing on tape bars while observing for wire movement during pressing. If no movement occurs, gage is ready for tack coat.

7. **Tack Coat**

Place specimen in vise or suitable holder and position vortex cooling air nozzle so the cooling air is along tape bars and at about 20 degree angle from surface. Turn cooling air to 30psi. Ignite gun. Turn gun on. Spray at about 10" distance. Hold gun at idle in a position which imparts no heat into the specimen. Hold gun perpendicular to gage surface and apply Rokide with rapid passes followed by several seconds of dwell with gun in idle position. Spray technique is best developed on other gages, such as Pt-W types. The technique should apply no more than 400°F to gage grid maximum, (see Reference 2) and grid should return to room temperature before making the next pass. The gage should have no measurable change in resistance when correctly applied.

The tack coat uses less than 8" of rod and takes 25 to 30 passes. The gage should be lightly pressed with the thumb before the 1st pass and before each subsequent pass to be sure tape is in intimate contact with pre-coat. If tape adhesive lets go and several spray passes are made, the tape will loose all stickiness and the gage must be removed, or the tape bar replaced.

The gage should be examined continually to view progress and spraying should stop when enough material is deposited to barely hold the gage in place. The leads will not be covered! They will just be partly covered. If the leads are covered, too much material has been applied. The Rokide is semi-transparent and in thin layers, the leads and grid are quite visible. It is better to periodically stop spraying and examine under a microscope, and add material if required, than to apply too much to begin with. The microscope for this examination should be turned up to

25x or 30x for a good look. What looks like inadequate coverage at 7x may at times really be adequate when viewed at 30x.

8. **Tape Removal**

Remove all perimeter tape down to the grid tape bars. While viewing at 15x, using sharp tweezers, remove shading tape bars. Grasp tape carrier tab with tweezers and pull over itself and at 45° to the gage axis. Pull slowly while observing under scope. Be sure all adhesive stays with the tape. Do not pull upward on grid. Upward pulling can pull grid out of Rokide or stretch grid wire. Pull carefully. Pull slowly. The stretched adhesive will slowly let go of the gage. If a piece of adhesive breaks off, it must be removed. After tape removal, examine gage carefully and remove any debris using an artists brush. Then dip the brush in M.E.K. and apply to former tape area. If any tape residue remains, it will swell from the M.E.K. and become visible for removal. The artists brush or sharp tweezers are used to remove any tape residue. Check gage resistance.

9. **ReMask and Final Coat**

Apply a single layer fiberglass tape perimeter about 1/64 to 1/32 beyond previous perimeter tape. Examine under 15x after all taping. Place gage in vise and turn on Vortex air. Spray final coat using same technique as before. When complete, there may be 2-6" of rod remaining. Do not apply too thick. Remember, the Rokide is semi-transparent. Lead shape will be visible. If coating over leads turns all white the coating is too thick. Check gage resistance with gage at room temperature.

10. **Remove all tape.**

Dress any sharp corners using aluminum oxide stone.

11. **Install thermalcouple per instructions by K. Krake.**

Figure 1. Constant stress bar ready for gage installation.

Figure 2. Nickel chrome aluminum pre-coat applied to gage bond areas.

Figure 3. Thin insulating coat of alumina, 4% Zirconia is applied to gage bond area.

Figure 4. Photo of free filament PdCr/Pt dual element strain gage with temporary teflon fiberglass carrier. The leads are .003" Dia. PdCr Gage is temporarily stored on glass slide covered with release paper.

Figure 5. Sketch of a free filament PdCr/Pt dual element high temperature strain gage. Note the platinum compensating element is positioned on both sides of strain sensing PdCr grid to thermal balance temperature gradients across grid. The .003" Dia. leads are designed to minimize stresses on the weld junction and to prevent rotation of the lead during bonding.

Figure 6. Gage is removed from slide with tweezers and positioned on test bar.

Figure 7. Photo of gage in position on test bar.

Figure 8. Photo of .030" wide tape bars placed over platinum crossover strand.

Figure 9. Sketch of gage showing placement of tape over platinum crossover wire and the placement of aluminum teflon tape over the .003" diameter leads. Note the tape does not touch the .001" grid.

Figure 10. Photo showing tack coat applied and tape bars removed.

Figure 11. Gage perimeter masked in preparation for final coating.

Figure 12. Completed gage installation on constant stress test bar.

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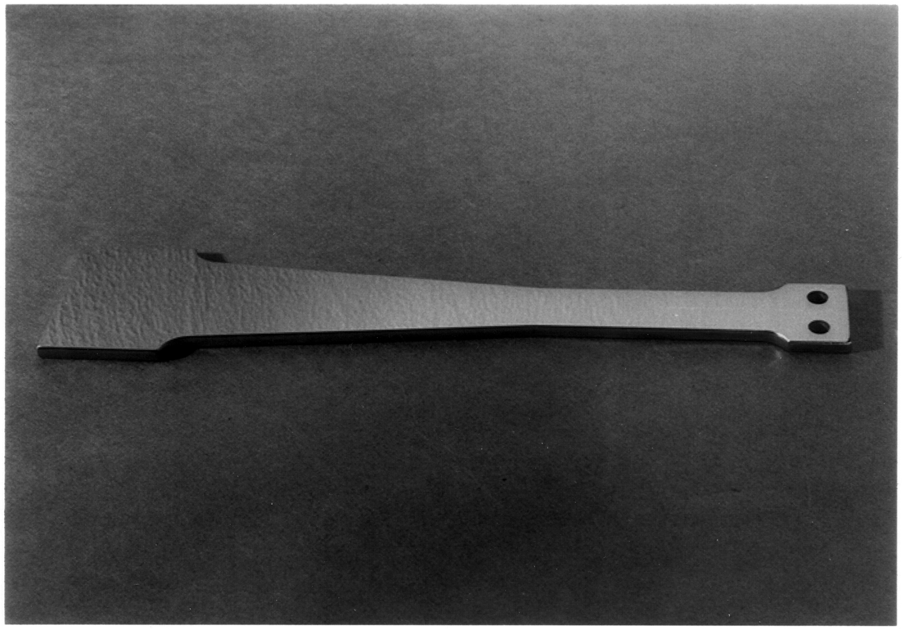

FIGURE 1. Constant stress bar ready for gage installation.

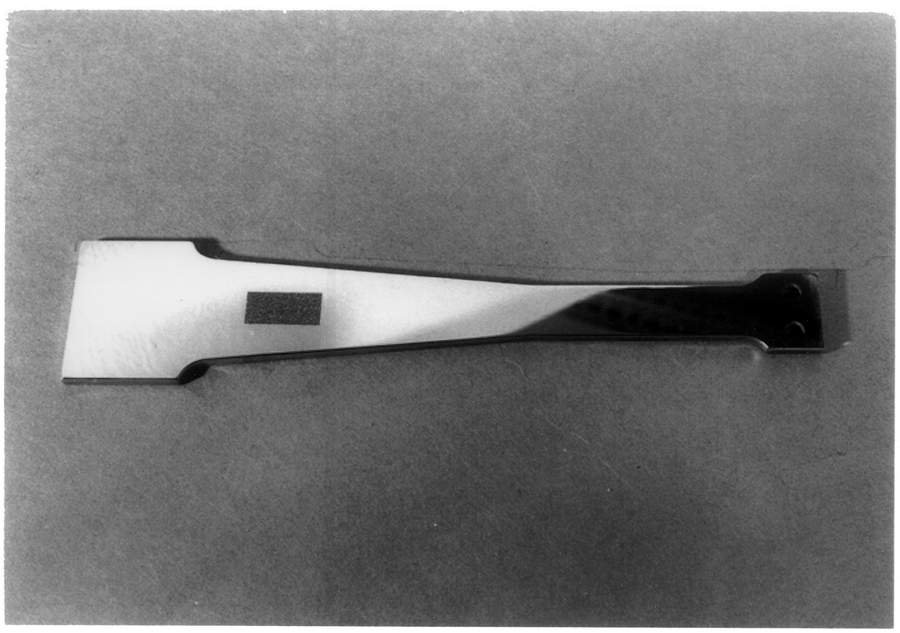

FIGURE 2. Nickel chrome aluminum precoat applied to gage bond area.

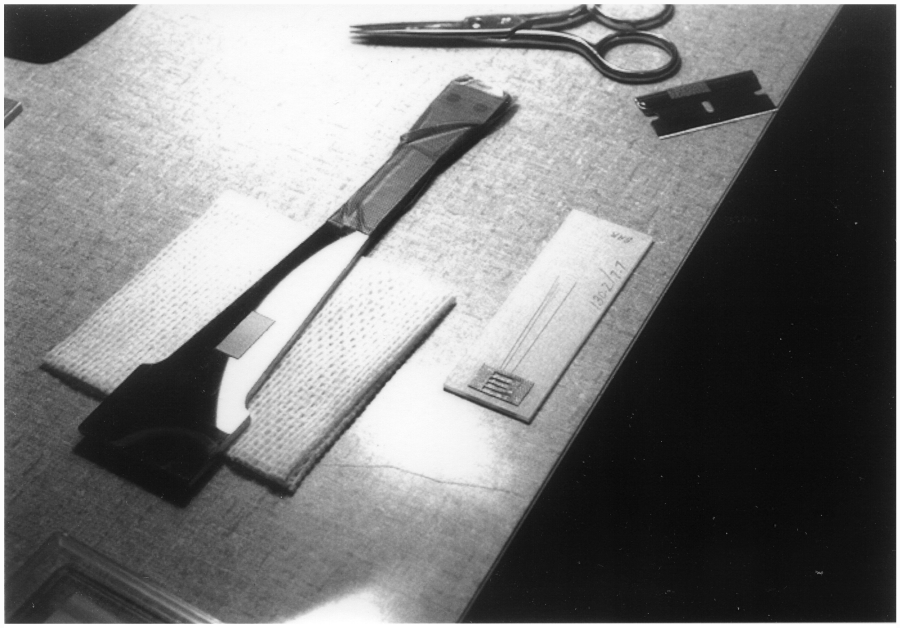

FIGURE 3. Thin insulating coat of alumina, 4% zirconia is applied to gage bond area.

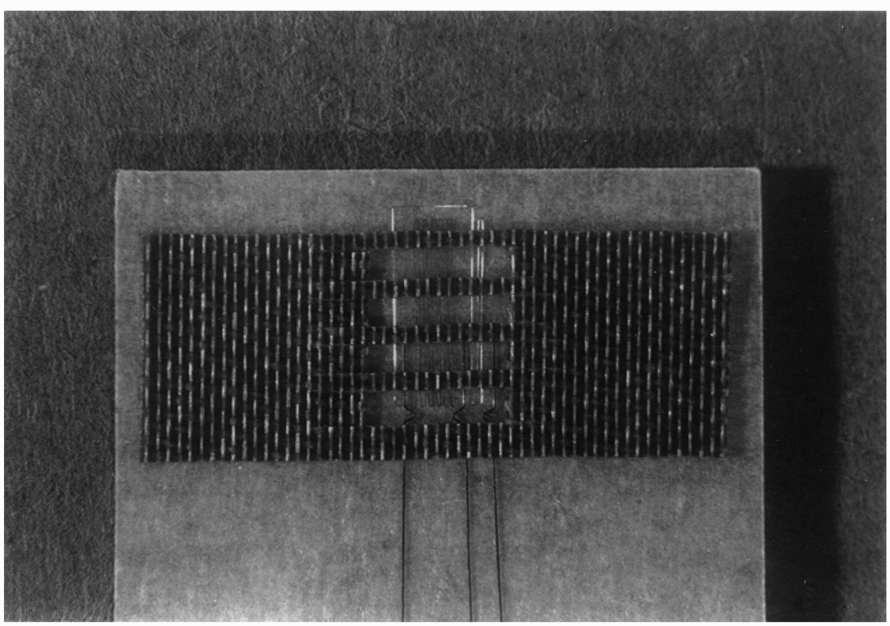

FIGURE 4. Photo of free filament PdCr/Pt dual element strain gage with temporary teflon fiberglass carrier. The leads are .003" diameter. PdCr gage is stored on glass slide covered with release paper.

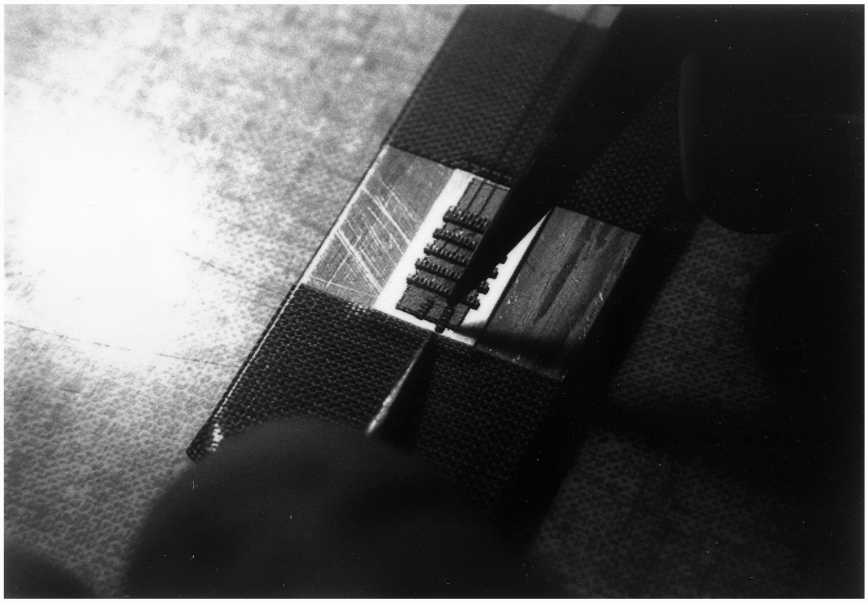

FIGURE 8. Photo of .030" wide tape bars placed over platinum crossover strand.

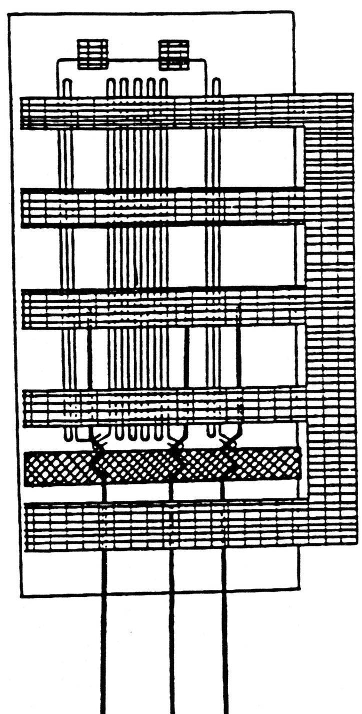

FIGURE 9. Sketch of gage showing placement of tape over platinum crossover wire and the placement of aluminum teflon tape over the .003" Dia. leads. Note the tape does not touch the .001" Dia. grid.

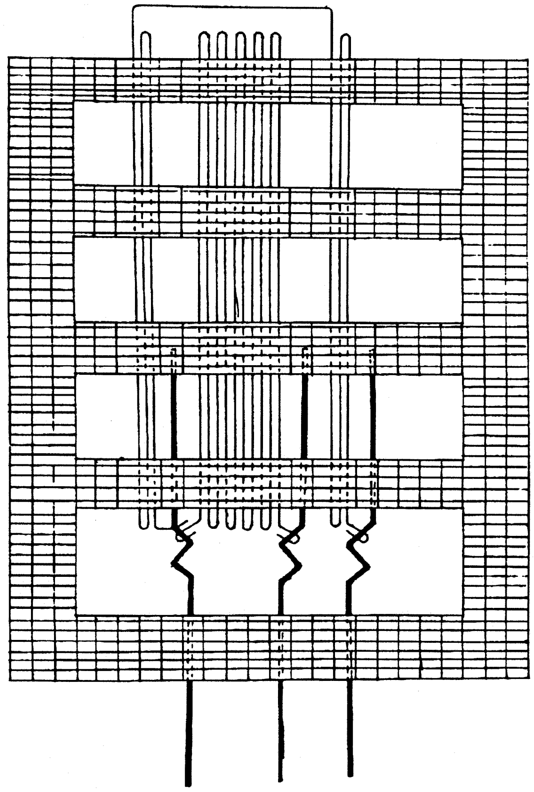

FIGURE 5. Sketch of a free filament PdCr/Pt dual element high temperature strain gage. Note the platinum compensating element is positioned on both sides of strain sensing PdCr grid to thermal balance temperature gradients across grid. The .003" Dia. leads are designed to minimize stresses on the weld junction and to prevent rotation of the lead during bonding.

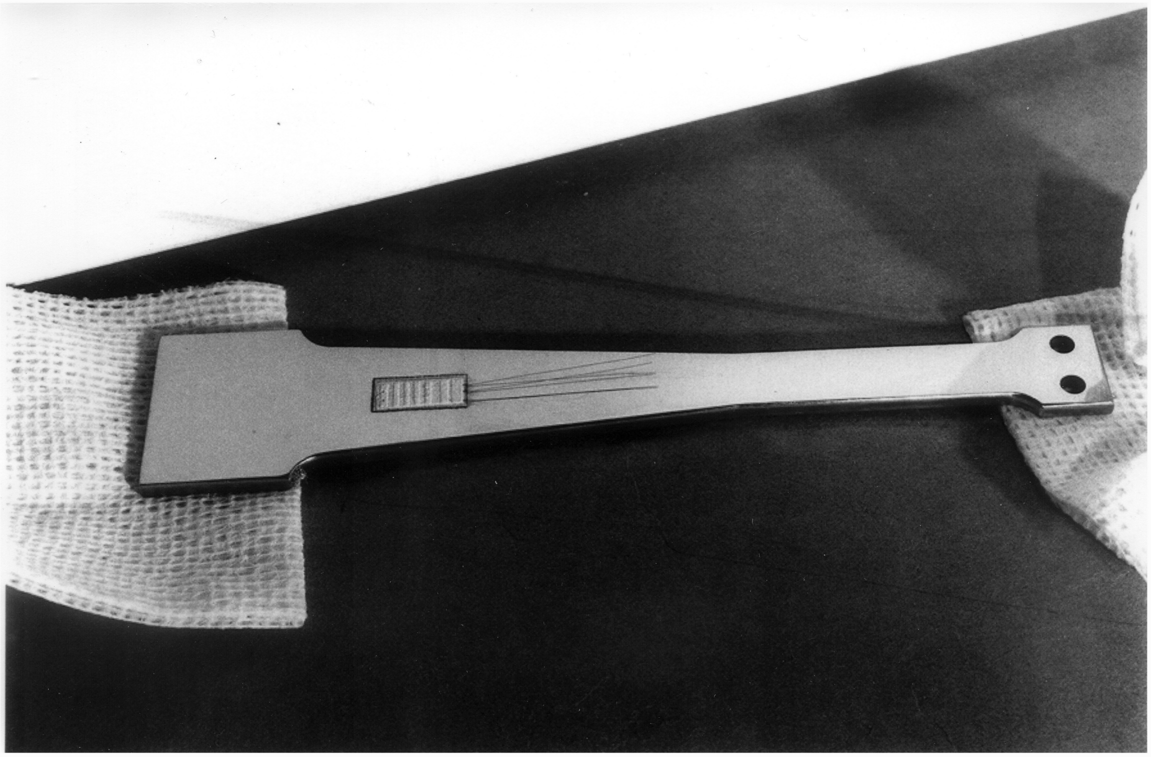

FIGURE 12. Completed gage installation on constant stress test beam.

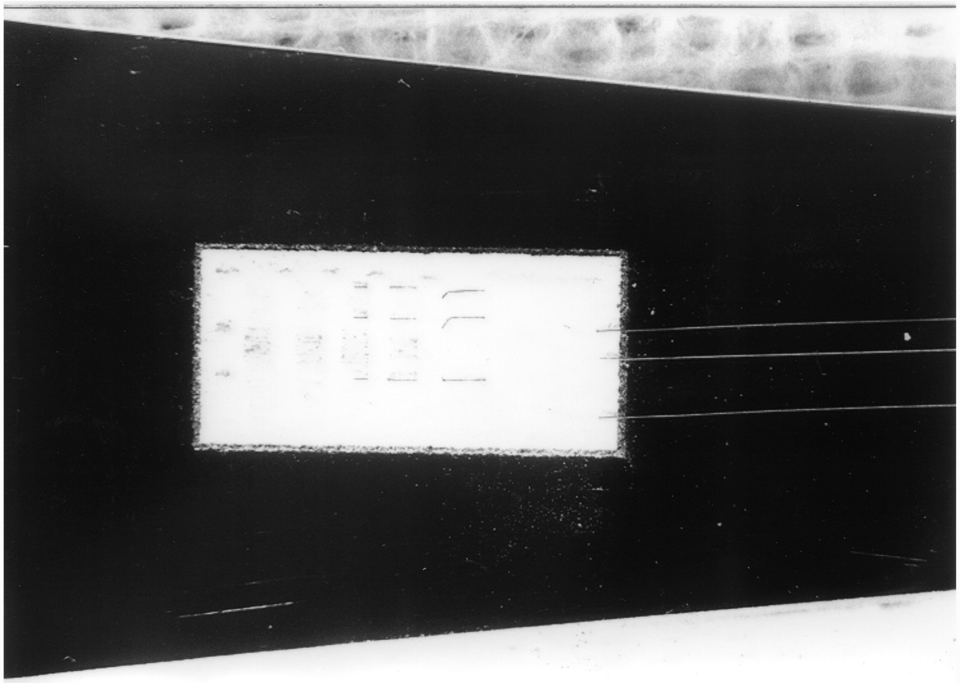

FIGURE 10. Photo showing tack coat applied and tape bars removed.

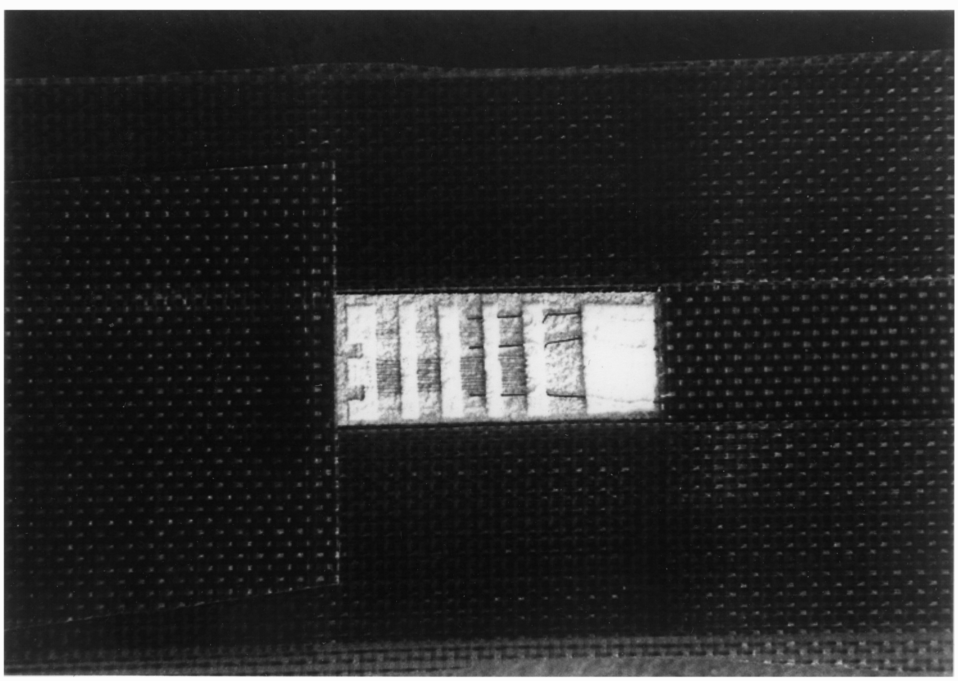

FIGURE 11. Gage perimeter masked in preparation for final coating.

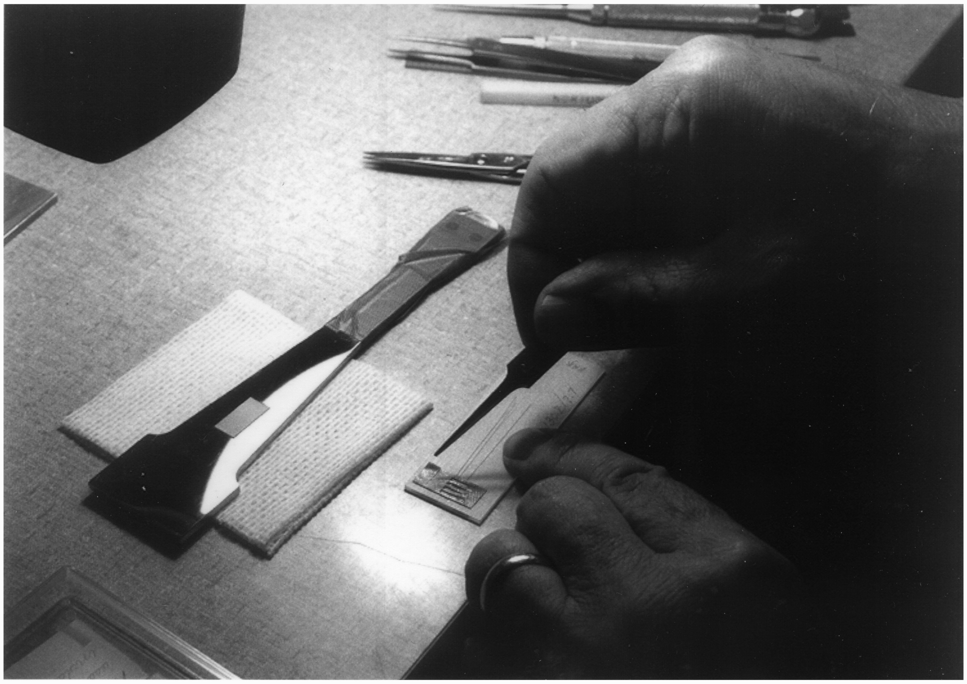

FIGURE 6. Gage is removed from slide with tweezers and positioned on test bar.

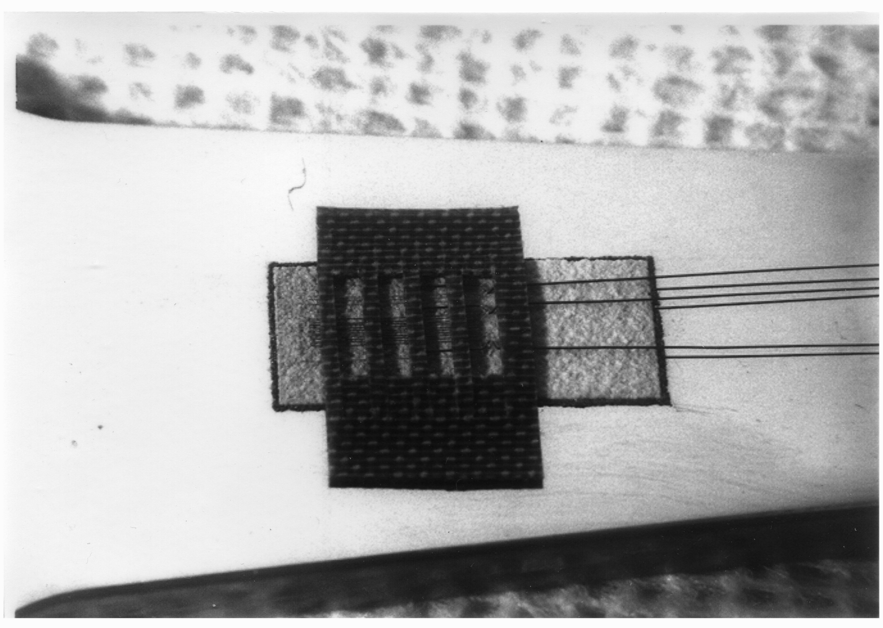

FIGURE 7. Photo of gage in position on test bar.

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13. ABSTRACT ***(Maximum 200 words)***

This document contains the installation procedure employed under NASA contract NAS3–27038. They represent the state of the art at the time of this project.

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